Dynamic Lane Allocation at Signalized Intersections

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Background (1)

EAR Project -- Advanced Signal Control Strategies
Develop control strategies based on real-time Connected Vehicle data, and evaluate their performance
PATH/UC Berkeley, UC Riverside, BMW

Major Tasks:

- **Estimating of performance measures from probe data**
  - Determine penetration rates and sampling protocols
  - Data fusion with loop detector data

- **Traffic signal control for mobility**
  - Queue spill-back avoidance
  - Perimeter control in grid networks to prevent gridlock
  - Dynamic lane grouping

- **Traffic signal control for safety**
  - Dynamic all-red extension
  - Minimizing arrival rate on yellow change interval

- **ECO signal operations**
  - In-vehicle driver speed advisory for minimum fuel consumption
  - Integration of adaptive signal priority with driver advisory
Background (2)

Temporal & spatial variation in traffic demand

Source: Yin Y, Robust optimal traffic signal timing, Transportation Research, Part B, 42 (2008)
Problem Statement

- Most signal control strategies assume fixed lane utilization on intersection approaches
- Spatial variations in traffic demand degrade intersection performance
- Solutions for predictive situations (TOD lane assignments)
Dynamic Lane Allocation/Grouping (DLG) (1)

- Changing lane allocation in response to real-time movement demands
- Allows exclusive and shared lanes

Requirements
- O-D information
  *(Connected vehicles)*
Dynamic Lane Allocation/Grouping (DLG) (2)

Focus of our paper

Assumed demand is known and can be predicted
Visualization of Demand Variation

For a single signalized intersection approach

- Total demand (LT + TH + RT movements) is fixed
- Movement LT, TH and RT demands vary
Given real-time O-D demands at a signalized intersection, how to dynamically determine the lane assignment to improve performance?

**Approach:**
- For each intersection leg find the optimum lane grouping 
  Minimize the max lane flow ratio $y$
  $(y = \text{flow/saturation flow})$
- **St:**
  Allowable movements (safety constraints)

**Sub-problem:**
Determine the steady state traffic flow among lanes within each lane group also.
Evaluation of DLG

Numerical Analysis

- Scenarios:
  - Keep total demand fixed
  - Increase total demand (oversaturated conditions)
    - Demand ratio among movements
    - # Lanes per approach
    - Fixed timing vs. “adaptive” timing
      (EQUISAT or HCM2000 QEM)

- MOEs
  - max lane flow ratio
  - average delay sec/veh (per HCM)
Evaluation of DLG

Simulation

- PARAMICS microsimulation model
- Plug-in for Environmental Measures
- MOEs: Delay, Stops, Fuel, Emissions
  - Four leg eight phase intersection
  - Four lanes/approach
  - Fixed cycle length C=120 sec
Results: Max Lane Flow Ratio/Lane (1)

Under DLG, max lane flow ratio always keeps as low as 0.2
Results: Max Lane Flow Ratio/Lane (2)

Higher DLG benefit in terms of max lane flow ratio when demand deviation increases
Performance Analysis: Average Delay

Under DLG scenario, average delay remains almost constant
Simulation Experiments (1)

Average Delay (sec/veh)

% LT = 0.3

% LT = 0.68

Baseline

Fixed LG

Optimal Timings

DLG Fixed Timings

DLG--Optimal Timings

MODEL

PARAMICS
Simulation Experiments (2)

![Graph showing Average Delay (sec/veh) vs % Left Turns with FIXED and DLG markers.](image-url)

- **Average Delay (sec/veh)**
  - Y-axis: 0, 20, 40, 60, 80, 100, 120, 140, 160
  - Values range from 0 to 160
- **% Left Turns**
  - X-axis: 0.2, 0.4, 0.6, 0.8
  - Values range from 0.2 to 0.8
- **Markers**:
  - FIXED: Blue line
  - DLG: Green line
Discussion

- Findings:
  - Dynamic lane allocation appears promising to address spatial demand variation
  - Improves efficiency and robustness
  - Higher benefits for multilane approaches

- Challenges:
  - Need O-D demands
    - Existing and emerging technologies
  - Safety issues and potential capacity reduction:
    - Induced lane changes
    - Lane transition in and out
    - Driver expectancy warning

- Opportunities:
  - Integration with adaptive signal control strategies